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ABSTRACT

This paper describes Topdown Conceptual Analysis (TCA) and how it can be used to produce the knowledge base for the development of courseware. Some of the prerequisites and basic theories behind TCA are explained. In discussing what is meant by learning and teaching a concept, an explanation is given of how a complex concept can be taught in terms of simpler or contributory concepts. The importance of examples and non-examples in learning and teaching a concept is emphasized. A discussion is presented on how the methods and techniques of TCA were used to develop the courseware called "Introductory New Mathematics for Parents and Children." Relationships within concepts are demonstrated with diagrams. References and a bibliography are included. (JD)

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COURSEWARE DEVELOPMENT BY TOPDOWN CONCEPTUAL ANALYSIS

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Key Words: Topdown Conceptual Analysis, Conceptual Structure, Subordinate Concepts, Coordinate Concepts, Supra-ordinate Concepts, Generalization, Discrimination & Chains.

ABSTRACT

This paper describes the methods and techniques used to design and develop the courseware called INTRODUCTORY NEW MATHEMATICS FOR PARENTS & CHILDREN, using authoring systems like SCENARIO which has been used by teachers in Quebec and the US to produce courseware with little help from programmers.

The methods and techniques that have been used are called Topdown Conceptual Analysis (TCA) which takes most of the guesswork out of the design of knowledge-based systems. Given a list of specifications of objectives and a description of the target population , different groups of people who are trained in TCA, and working independently, should be able to generate - without involuntary omissions or repetitions - equivalent knowledge bases to build a system.

1. INTRODUCTION

In this paper we present the notion of TCA and how it can be used to produce the knowledge base for the development of the courseware. We explain some of the prerequisites and basic theories behind TCA. We discuss what is meant by learning and teaching a concept, and how a complex concept can be taught in terms of simpler or contributory concepts. We emphasize the importance of examples and non-examples in learning and teaching a concept, and then we discuss how we used TCA to develop the courseware called INTRODUCTORY NEW MATHEMATICS FOR PARENTS AND CHILDREN.

2. THE PROBLEM OF DEVELOPING HIGH-QUALITY INSTRUCTIONAL MATERIALS

2.1 A Great Composition: MIT Professor Jerrold Zacharias suggested in a 1956 memorandum which led to the creation of the Physical Science Study Commission (PSSC) that, "Education is like hi-fi. To have a good hi-fi, you need a good performer on a good day, a good recording, a good pressing of it, a good pick-up and amplifier; you need a room with good acoustical qualities and a person with the intent to listen. But most important of all is the composition itself; without a great composition, everything else is pointless." Silberman (1970)

2.2 Cooperation Between Knowledge Engineers & Domain Experts: The planning of a good learning system development project ideally provides for close cooperation between knowledge engineers (KE) and domain experts (DE). The DE usually holds a higher position than the level for which the system is to be built. He (for brevity's sake, we shall use masculine pronouns for both genders) should know the domain of his field thoroughly as well as the problems encountered at various levels

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within the specialization. The KE applies learning theories to the practical task of learning and teaching. Ideally he should have also acquired the methods and techniques of TCA.

2.3 Allocation of Responsibilities: Although a course can be developed by one KE working with one DE, or by a person acting as both, it is better to have one KE working with several DEs, programmers, artists and editors, to ensure quality and reduce the costs.

2.4 Set of Steps: While designing a learning system, the KE and the DE go through a set of such steps as:

1. Determining the needs
2. Identifying the problem
3. Specifying the target population of learners
4. Specifying pre-requisite entering behavior
5. Specifying terminal behavior
6. Generating the knowledge base (NB)
7. Converting KB into story-boards
8. Testing and revising until the materials meet specifications
9. Entering the materials into the computer
10. Testing and revising the courseware,etc.

Some textbooks explain quite clearly how to perform all the steps except Step Six: "Generating the knowledge base". The success of a learning system depends on the quality of the knowledge base. It is the raw material with which we build a learning system, and it is the Topdown Conceptual Analysis that generates that raw material.

3. SOME THEORIES BEHIND TCA

3.1 Introduction: The term Topdown Conceptual Analysis may be new but the idea of TCA is not. Every good teacher or educator has been using it in some form or other without realizing that it is called TCA.

3.2 Some Examples: In his Discourse on the Method (1637), René Descartes was certainly using a topdown technique when he wrote about dividing each problem into as many parts as feasible and requisite for the solution of a problem. Unfortunately Descartes never showed us exactly how to go about such division.

According to Richard Skemp (1971), "Concepts of higher order than those which a person already has cannot be communicated to him by a definition, but only by arranging for him to encounter a suitable collection of examples. And since in mathematics these examples are almost invariably other concepts, it must first be ensured that these are already formed in the mind of the learner." In other words, lower-order concepts must be present before the next stage of abstraction is possible. In building up the structure of successive abstractions, if a particular level is imperfectly understood, everything from there on is in peril. This dependency is greater in mathematics and related domains than in any other domain. One can understand and learn the geography of Asia even if one has missed that of Europe; one can understand and learn the history of the nineteenth century even if one has missed that of the eighteenth. To understand algebra without having really understood arithmetic is an impossibility. To learn calculus without having a working knowledge of algebra, trigonometry, and analytic geometry is not possible.

Robert Gagné (1985) maintains that readiness to learn is essentially a

function of pre-requisite learning. "Ensure that he has acquired the pre-requisite capabilities and he will be able to learn. When he is capable of tasks d & e (Figure 1), he is ready to learn b; when he is capable of tasks f & g, he is ready to learn c; and when he is capable of tasks b & c, he is ready to learn a", which is the most abstract concept or task in the hierarchy.

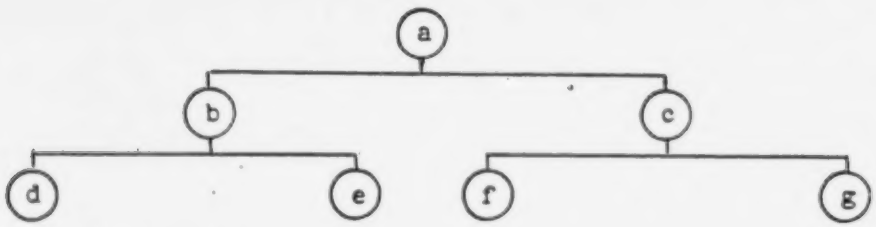


Figure 1: Tree diagram representing a hierarchy

Ausubel (1960), who is in agreement with Gagné on this issue, has stated the point eloquently thus: "If I had to reduce all of educational psychology to one principle, I would say this: "The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly."

4. TOPDOWN CONCEPTUAL ANALYSIS

In practice, what Skemp, Gagné and Ausubel say amounts to this: before one can understand and learn a new concept, one has to discover and learn its subordinate concepts and related rules, and so on, until one reaches those one already knows. Unfortunately, Skemp, Gagné and Ausubel have not shown us how to discover the subordinate concepts of a concept - at least in a concrete, simple and systematic way.

Le Xuan & Chassain (1975, 1985) have developed a method and technique which allows us to generate - without involuntary omissions or repetitions - all the necessary subordinate concepts and rules of any concept, rule, principle or text. It is called Topdown Conceptual Analysis (CTA). Doing a TCA is like decomposing a composite number into its prime factors. If one has to factor the number 24, for instance, one will always obtain the prime factors 3, 2, 2, 2, no matter how one decomposes the number 24, as shown in Figures 2, 3, and 4.

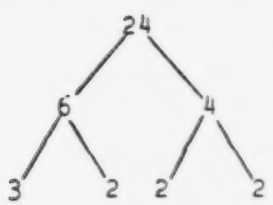


Figure 2

or

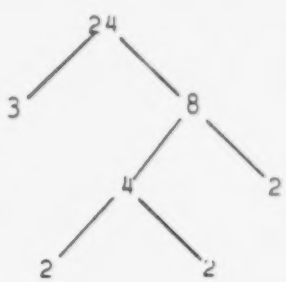


Figure 3

or

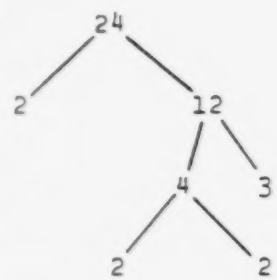


Figure 3

5. SOME PRE-REQUISITES TO TCA

5.1 Relations: Relations are links that connect objects. Relations are usually represented by verbs, verbal phrases, arrows or any sym-

bol. The following underlined verbs and verbal phrases are examples of relations:

5.1.1 Peter loves Jane. Notation: loves(Peter,Jane) arrow diagrams: Peter ⟶ Jane. This relation connects two objects: It is a binary, dyadic or two-ary relation.

5.1.2 Peter gives a book to Jane. Notation: gives-to(Peter,book,Jane) This relation connects three objects: It is a ternary, triadic or 3-ary relation.

5.2 Concepts: Concepts are classes or categories of

1. objects (table, computer, chair, man,etc)
2. qualities (good, bad, large, narrow,etc)
3. quantities (one, two, much, many,etc)
4. events (work, play, run,etc)
5. relations (above, below, west of, east of,etc)

5.3 Conceptual Structures: Conceptual structures are structures in which lower-order concepts are pre-requisites to higher-order concepts. A conceptual structure can be visualized by the following tree diagram (Figure 5).

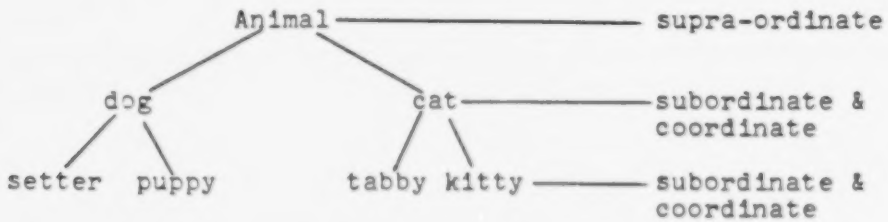


Figure 5: Tree diagram representing a structure

5.4 Chain: Chain is a technical term for what is sometimes called procedure, sequence of action, or reasoning sequence. A more precise definition of chain is "a sequence of stimuli and responses where each response produces the stimulus for the next responses, and so forth." Some common examples of chain are: (1) uttering a sentence; (2) performing an experiment,etc.

5.5 Generalization: Generalization is a technical term for what is commonly called "lumping things together," "seeing similarities," or "disregarding differences." This leaves open the question of whether or not a generalization is appropriate or inappropriate, desirable or undesirable. A more precise definition of generalization is "making the same kind of responses to different stimuli (objects)." The following are some examples of generalization.

5.5.1 Saying "good morning" to all kinds of people, regardless of what time of the day it is so long as it is before noon.

5.5.2 Saying "dog" in the presence of setters, puppies, pointers, regardless of whether the animals are brown or black.

5.5.3 Proceeding when the traffic light is green, regardless of whether

the light is suspended or on a post, regardless of whether you are in a car or on foot, and regardless of whether it is morning, noon or night.

5.6 Discrimination: Discrimination is a technical term for what is commonly called "making distinction,""classifying," or "categorizing." A more precise definition would be "a tendency to make one kind of response in the presence of one kind of stimulus situation, and another kind of response in the presence of other kinds of stimulus situations. Note again, that this leaves open the question of whether or not the discrimination is the desired or the appropriate one. Discriminations may be either correct or incorrect, desirable or undesirable. The following are common examples of discrimination.

5.6.1 Saying "good morning" before 12 and "good afternoon" after 12.

5.6.2 Proceeding when the light is green & stop when the light is red.

5.7 When Can We Say That an Individual Has Learned a Concept? In other words, what must he do to show that he has learned a concept.

1. He must be able to generalize within a class of objects, qualities, quantities, events and relations; and

2. discriminate between that class and other classes.

5.7.1 Example: When an individual makes the same response "triangle" to each member of class T (Figure 6), and the same response "rectangle" to each member of class R, he is generalizing within a class of triangles and a class of rectangles; he is also discriminating between a class of triangles and a class of rectangles. The psychologist would say that the individual has learned the concept of triangle and the concept of rectangle.

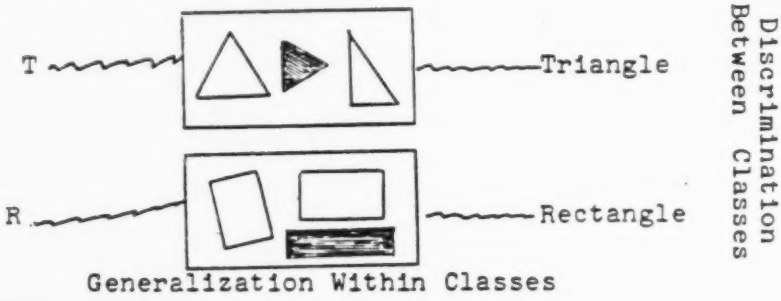


Figure 6: Generalization & Discrimination Between Classes

5.7.2 Non-example: When an individual is capable of recognizing a dog, but is unable to distinguish a dog from a fox, he has not learned the concept of "dog".

5.8 How To Teach a Concept: When one analyzes the behavior of the learner to see what he does when he learns a concept one sees that the learner generalizes within a class and discriminates between that class and other classes. Now what does the teacher do when he teaches a concept? He creates situations which will allow the learner to generalize and to discriminate among things; that is, he provides the learner with enough examples and non-examples. Suppose one has to teach the concept of primitive term to an adult learner, here is one way one can proceed:

A. Tell him why he should learn the concept of "primitive term". This is the introduction:

"To define a term (word) we must use other terms, but we cannot go on defining terms for ever. We must at some stage reach terms which cannot be defined by other terms without turning in circles. Such terms are called primitive terms."

B. Show the learner at least two examples of the term "primitive term", as one cannot generalize from one example:

"Terms such as 'point', 'line', 'plane',etc cannot be defined without using less familiar terms. Point, line & plane are said to be primitive terms." Note that some concepts need more than two examples before the learner can learn to generalize within classes.

C. Next, show the learner as many non-examples as necessary so that he can discriminate between "primitive terms" and "non-primitive terms":

"Terms such as 'addition' and 'subtraction' can be defined by more familiar terms, but sometimes we do not need to define them because most people (or at least the people for whom the material is designed) alread know how to use these two terms. In this case, 'addition' and 'subtraction' are called undefined terms."

D. If necessary, show the learner another non-example:

"The term 'mortar' can be defined as 'a mixture of cement, sand, and water used for holding together bricks and stones. 'Mortar' is a derived term. It is derived from the terms 'mixture','cement' and'water'.

E. Perhaps it is now time to give the learner a test to see if he can recognize a primitive term among different types of terms:

"Which of the following are primitive terms: table, on, the, an? Answer: on, the, an are primitive terms, because they cannot be defined without using less familiar terms."

F. Next, give the learner another test to see if he can give an example of 'primitive term' other than point, line & plane:

"Give another example of 'primitive term'." "Answers: or, at, in, out,etc."

G. Next come the definitions, because by this time the learner should be able to define 'primitive term', 'undefined term' and 'derived term'.

"Define 'primitive term', 'undefined term' and 'derived term'. Answers: (1) A primitive term is a term that cannot be defined without using less familiar terms; (2) An undefined term is a term that can be defined by more familiar terms but which we do not want or need to define; and (3) A derived term is a term that has been defined by other terms.
Note: More examples and non-examples might be needed for some learners. All depends on the level of pre-requisite knowledge of the learners and the complexity of subject matter to be taught.

5.9 Positive & Negative Examples: We see that (1) to teach a concept we must teach the learner to generalize within a class and to discriminate between that class and other classes; (2) to teach the learner to generalize and to discriminate, one must present him with enough positive examples (or simply examples) and negative examples (or non-examples) of the concept to be taught.

5.9.1 Examples of Pos. & Neg. Exs. (1) A foxhound belongs to a class of objects called DOG. A fox hound is said to be a positive example of of the concept dog; (2) A fox which looks somewhat like a dog but is not a dog: a fox is said to be a negative example (or non-example) of the concept dog; (3) Chair is an excellent negative example of stool, because both have the same attributes except one: a chair has a back whereas a stool does not.

5.9.2 Definitions: (1) A positive example (or simply example) of a class or concept is the member of that concept or class; (2) a negative example (or non-example) of a class or concept is the member of a class which is similar to but different from the class or concept under investigation.

5.9.3 Different Forms of Examples: A example may be an experiment, object, diagram, table, photograph, description, explanation,etc.

6. USING TCA TO GENERATE THE KNOWLEDGE BASE

6.1 Introduction: The knowledge base is the raw material with which we build learning systems. It is made up of two component parts: the declarative knowledge structure which contains concepts, rules, facts, opinions or principles; and the procedural knowledge structure which contains procedures to perform such tasks as experiments to illustrate science concepts which call for experiments, or such tasks as starting a car, or changing a tire.

The following is the TCA the authors have developed to generate the knowledge base for the development of the first lesson: SET. It is the first component part of the INTRODUCTORY NEW MATHEMATICS FOR PARENTS & CHILDREN. The knowledge bases for the rest of the course were generated in the same manner. This TCA was developed from the term SET, but a TCA may also be developed from any stimulus: a symbol, phrase, diagram, photograph, sentence or a test with or without answers.

6.2 Procedure

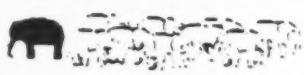
TCA : Set
Part A : Input-output Inventory

Input	*Output*
1.0 Set →	*2.0 Introduction: This is a step-by-step study course in the INTRODUCTORY NEW MATHEMATICS FOR PARENTS & CHILDREN. The concepts presented are: set, one-to-one matching, expanded notation, inverse operations and arithmetic properties. In this lesson we shall see what is meant by the term SET.*
	3.0 Examples of Sets:
	3.1 This is a collection of stamps: The mathematician would say "a set of stamps."

1.0 Set

3.2 This is a group of people: We can also say "a set of people".

3.3 This is herd of elephants: We can also say "a set of elephants".



4.0 Definition: A set is a collection, group, herd or family of objects or things. The things that make up a set are called members or elements of that set.

5.0 Related Rule: A collection, group or herd must be well-defined to be a set; that is, given an object, we must be able to tell immediately whether or not that object is a member or an element of that collection or group.

6.0 Examples of Well-defined Collections

6.1 Consider the collection of letters: a, b, c, d, & e. Given an object f, for instance, one can tell immediately that f is not a member of that collection of letters.

6.2 Consider the collection of numerals: 1, 2, 3, 4, 5 & 6. Is the object 3, for instance, an element of the collection? We can tell immediately that 3 is an element of the collection. The collection of letters and the collection of numerals are well-defined collections.

7.0 Examples of Not-well-defined Collections

7.1 The collection of "beautiful" paintings cannot become a set, because given a painting, it is not possible to tell whether or not the painting is beautiful: not everybody agrees on what is beautiful and what is not.

7.2 The group of "intelligent" boys is not well-defined, because not everybody agrees on which boy is intelligent and which boy is not.

8.0 Exercises

(a) Is the "collection of carpets" well-defined?

(b) Is the "collection of beautiful rugs" well-defined?

(c) Is a "group of well-dressed men" well-defined?

(d) Is a "group of psychologists" well-defined?

(e) Define "set" and "element of a set".

(f) When can we say that a collection of things is well-defined?

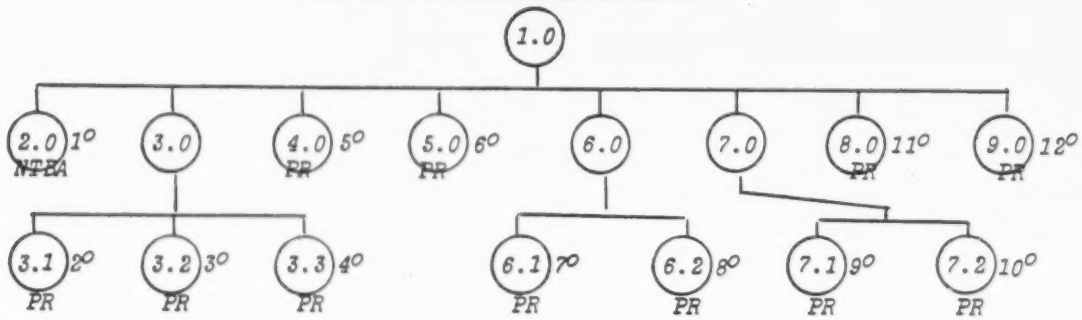
(g) What is the mathematical term for collection or herd?

9.0 Answers

(a) The "collection of carpets" is well-defined.

1.0 Set →	9.0	(b) The "collection of beautiful rugs" is not well-defined because not everybody agrees on the meaning of the term 'beautiful'. (c) A "group of well-dressed men" is not well-defined, because not everybody agrees on the meaning of the word 'well-dressed'. (d) A "group of psychologists" is well-defined in the western world. (e) A set is a collection or group of objects; and the objects that make up a set are called members or elements of that set. (f) We can say that a collection is well-defined when given an object we can tell immediately whether or not the object is an element of that set. (g) The mathematical term for collection or herd is set.
2.0 Introduction: This is ... →	NTBA	Short for Not To Be Analyzed, by which we mean that, by convention, we shall not break down the content of this item, as each of the new concepts announced here will be treated later in the analysis proper.
3.0 Examples		
3.1 This ... →	PR	Short for Pre-Requisite, by which we mean that this item contains no new terms which call for further analysis (breakdown).
3.2 This ... →	PR	
3.3 This ... →	PR	
4.0 Definition →	PR	
5.0 Related Rule →	PR	
6.0 Examples		
6.1 Consider →	PR	
6.2 Consider →	PR	
7.0 Examples		
7.1 The →	PR	
7.2 The →	PR	
8.0 Exercises →	PR	
9.0 Answers →	PR	

TCA : Set
Part B : Representation of TCA



Note: The usefulness of this tree diagram would be more apparent if the domain is more complex. In the present case, we could visualize the hierarchy of the concept by mere inspection. 1° = 1st, 2° = 2nd, etc.

TCA : Set
Part C : Sequential Index

1°	(2.0 - 1.0)	Introduction
2°	(3.1 - 3.0)	1st example of set
3°	(3.2 - 3.0)	2nd example of set
4°	(3.3 - 3.0)	3rd example of set
5°	(4.0 - 1.0)	Definition
6°	(5.0 - 1.0)	Related Rule
7°	(6.1 - 6.0)	1st example of well-defined collections
8°	(6.2 - 6.0)	2nd example of well-defined collections
9°	(7.1 - 7.0)	1st example of not well-defined collections
10°	(7.2 - 7.0)	2nd example of not well-defined collections
11°	(8.0 - 1.0)	Exercises
12°	(9.0 - 1.0)	Answers to Exercises

TCA : Set
Part D : Converting the Sequential Index Into Story-Boards

Once the sequential index has been completed, it was converted into story-boards for the production of the program. The rest of the course was produced in the same manner.

6.3 How Was Part A Generated: To generate Part A of the analysis we proceeded as follows:

1. We divided each page into two parts, forming two columns: one for inputs and the other for outputs;

2. We recorded the material to be analyzed (the term SET) in the input column and numered it 1.0;

3. Input 1.0 produced eight outputs: 2.0, 3.0. 4.0, 5.0, 6.0, 7.0, 8.0, & 9.0;

4. Next, we drew a horizontal line under the 1st input & its eight outputs;

5. Then, we brought down output 2.0 (introduction) in the input column to turn it into an input, and recorded it under the line we had just drawn;

6. Input 2.0 produced NTBA, short for Not To Be Analyzed. This means that, by convention, we shall not analyze (breakdown) this item as it contains concepts which are analyzed elsewhere;

7. We drew another horizontal line;

8. We brought down output 3.0 in the input column to turn it into an input and wrote it under the line we had just drawn;

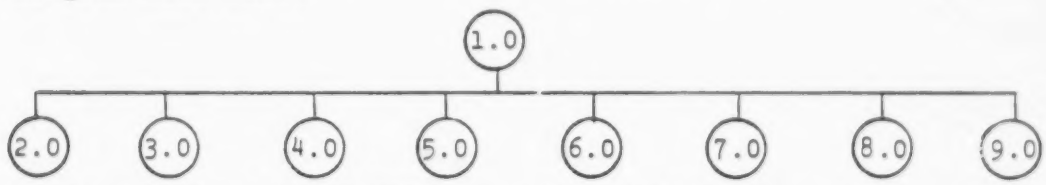
9. Input 3.0 produced PR, short for Pre-Requisite, by which we mean that we will not pursue our analysis any further, assuming that all the concepts in this item are known to the target population.

10. We drew another horizontal line.

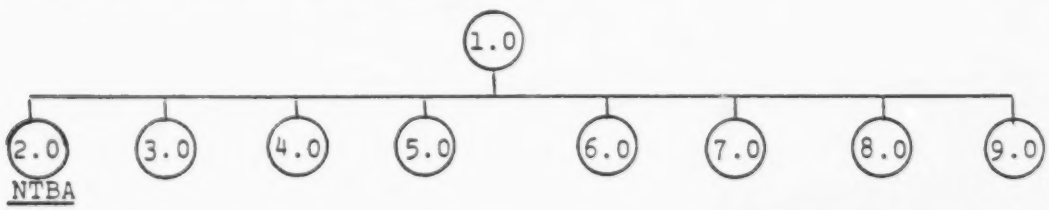
11. We brought down output 4.0 in the input column and treated it in the same manner until all the outputs were turned into inputs and produced PRs.

6.4 How Was Part B Generated: To reorganize the input-output inventory into a hierarchy or structure we proceeded as follows:

1. As one can see, input 1.0 produced eight outputs. We drew a tree diagram like this:



2. As input 2.0 produced NTBA, we added NTBA to the partial tree diagram which now looks like this:



3. We proceeded in the same manner until we exhausted all the inputs and outputs of the inventory and obtained the final tree;

4. The symbols 1^{o}, 2^{o}, 3^{o}, etc. represent the order of the component parts of the hierarchy. The ordering begins with the branches, from left to right, and from bottom upwards;

5. As one can see, the TCA begins at the top and moves downwards. But the concepts and rules or examples, represented by the nodes, are ordered from the bottom upwards. This means that the analysis proceeds from the higher-order concepts to the lower-order concepts, and the presentation of concepts, rules or examples, proceeds from the lower-order concepts to the higher-order concepts.

6. Note: When the domain is complex the tree diagram may occupy quite a large space. In that case it is necessary to break the tree diagram into as many branches as necessary. Some tree diagrams can give a sense of awe, but without the help of tree diagrams we will have to resort to intuition and guesswork which are usually more time-consuming.

6.5 How Was Part C Generated: To generate Part C we proceeded as follows:

1. We picked out the first item (1^o) on the tree diagram, then looked at the input-output inventory, and copied the content of 1^o on a separate sheet of paper. This is the first element of the structure.

2. Next, we picked out the second item (2^o) and copied its content. We proceeded in the same manner until the last item was disposed of. The end-result is the knowledge base with which we build the course.

3. Note: Usually the conceptual structure or knowledge base is made up of the following elements:

   .1 Introduction
   .2 Definition
   .3 Positive examples(or experiments)
   .4 Negative examples
   .5 Notation (if necessary)
   .6 Diagram or table or procedure
   .7 Related rules
   .8 Exercises with answers
   .9 References & bibliography

6.6 How Was Part D Generated: As the reader can imagine, Section 1, Step 1 represents the title of the program:

INTRODUCTORY NEW MATHEMATICS

FOR PARENTS AND CHILDREN

By

Albert Le Xuan & Rajjan Shinghal

With the Collaboration of a Group of
Parents & Children

Section 1, Step 2 represents the introduction:

> This is a step-by-step study course in the INTRODUCTORY NEW MATHEMATICS FOR PARENTS & CHILDREN. The concepts presented are: Set, one-to-one matching, expanded notation, inverse operations and some arithmetic properties. In this lesson we shall see what is meant by the term SET.

Section 1, Step 3 represents the first example of SET,and so one, until the learner can generalize within a class and discriminate between that class and other classes.

7. USING SCENARIO TO PRODUCE THE PROGRAM

7.1 What Can Scenario Be Used For: According to its authors, SCENARIO can be used for Writing, Drawing, Explaining, Learning, Teaching, Organizing, Telling, Having Fun, Composing Music, Buying & Selling, Being Heard, Being Seen, Questioning, Gathering Statistics, Simulating Conversation Events, Laboratory Experiments or Mathematical Models, Creating Interactive Software, Formative Documents, Images and Text Banks, Dictionaries, Animation, Video and Educational Games, or all of the above.

7.2 Scenario's Weakest Point: Scenario's weakest point is documentation. It is the number of errors that its manuals contain. What makes it more serious is that it is impossible to correct these errors with the three documents available because one cannot find the numbers of the items to be corrected, with the consequence that we have been obliged to grope around for quite a while before we can even enter the system, and even then we have not been able to find all the commands necessary for our work. It has not been easy to add graphics to the text so we have had to re-write the story-boards to "fit" Scenario.

8. STATUS OF INTRODUCTORY NEW MATHEMATICS FOR PARENTS & CHILDREN

We were half way through with the production of the program using SCENARIO when we discovered that we would succeed better with HYPERCARD which we will try out in May 1989. In the meantime we are using the methods and techniques of TCA to build a knowledge base for the development of the course entitled PATTERN RECOGNITION for beginning students of Artificial Intelligence.

9. HOW USERS USE TCA IN A CAL ENVIRONMENT

We believe that the methods and techniques of TCA are one of the most powerful tools for CAL systems designers. The following are some of the uses of TCA:

1. Generating knowledge bases for the development of CAL system;

2. Generating materials for the construction of tests: performance tests, pre-tests, post-tests, etc:

3. Measuring the level of difficulty of a term, sentence or text;

4. Teaching oneself new subject matters quickly and surely to be able to interact intelligently with domain experts.

What is really important about TCA is the idea that a concept, rule, task or any stimulus can be broken down into meaningful pieces, and that these pieces can be broken down into yet finer pieces, and so on, until one finally reaches a stage at which the detailed writing of line after line of a program is appropriate. 'Topdown Analysis' is an important phase in knowledge engineering (KEg), and it implies a from the abstract whole ('top') to the particular sub-components ('bottom'). An automobile engineer who starts his work by drawing blue-prints of a proposed car is using the topdown approach, whereas an engineer who starts by consulting a tyre catalogue is using the bottom-up approach. In the same manner, a knowledge engineer who starts his work by writing frames or lines is not using the topdown approach. Education is accomplished through a combination of bottom-

up and top-down approaches. Teaching is bottom-up - from the lower-order concepts to the higher-order concepts, and preparation for the teaching is top-down - from the higher-order concepts to the lower-order concepts.

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